AD-A195 594 DEVELOPMENT OF GRADED REFERENCE RADIOGRAPHS FOR ALUMINUM WELDS PHASE 1(U) INDUSTRIAL QUALITY INC GAITHERSBURG MD D POLANSKY ET AL. 07 MAR 88 1/1

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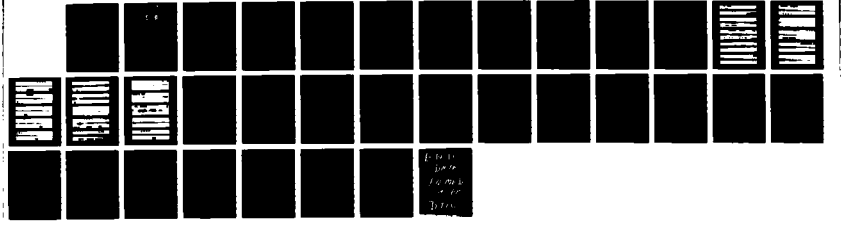

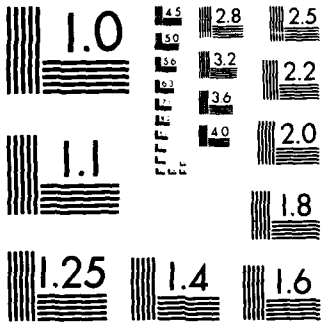

Development of Graded Reference Radiographs for Aluminum Welds

by

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Final Report, Army Contract
No. DAAK70-87-C-0027

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March 7, 1988

SUMMARY

The purpose of this Small Business Innovation Research Phase I project was to develop a data bank for graded sets of reference radiographs of aluminum welds. Reference radiographic documents of this type are extremely valuable for procurements related to ships, aircraft, other vehicles, construction and similar projects that include aluminum welds. The reference radiographs serve as a recognized way of acceptance or rejection of welds. There are no recognized standards for graded reference radiographs of aluminum welds. The only alternative at present is to use graded sets of reference radiographs for steel welds such as ASTM standard E-390. This is not a technically acceptable alternative because the radiographic contrasts and general appearance are different for steel welds as compared to aluminum welds.

During this Phase I project, a data bank of production radiographs of aluminum welds was collected. Several thousand radiographs are presently in the data bank. From this data bank, a set of proposed reference radiographs has been assembled. These include five grades of reference radiographs for three types of porosity, fine scattered porosity, coarse scattered porosity and linear porosity. The suggested reference radiographic document also includes three grades of clustered porosity, two illustrations of inadequate penetration, two illustrations of tungsten inclusions, and examples of longitudinal and transverse cracks, lack of fusion and undercut. This proposed set of graded reference radiographs covers the thickness rage 9.5 to 19mm (0.375 to 0.750 inch) for the 5000 and 6000 series of aluminum alloys.

It is proposed that this set of graded reference radiographs be used for procurement purposes and also for discussions with professional societies such as ASTM and AWS with the objective of arranging a formal society standard. Preliminary discussions with these societies and with ASNT, have been conducted during this project.

A follow-on project is suggested to expand the data bank to cover thinner material (0 to 9.5 mm [0.375 inch]), to prepare welds to back up the sets of graded reference radiographs and to continue work with professional societies in order to obtain a consensus standard that will be published and maintained.

PREFACE

This investigation, to identify a data bank for graded sets of reference radiographs of aluminum welds, was performed for the Department of the Army, Belvoir Research, Development and Engineering Center, Fort Belvoir, Virginia, under Contract Number DAAK70-87-C-0027. The project was a Small Business Innovation Research program. The period of performance was 7 July, 1987 to 7 March, 1988.

The Contracting Officer's Technical Representative was Mr. George D. Farmer, Jr., STRBE-VL. The authors are pleased to acknowledge the assistance and cooperation of Mr. Farmer and his associate, Mrs. K. Nesmith.

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INTRODUCTION

Aluminum structures are widely used for both military and industrial products, particularly in cases where low weight is important. Coupled with this increasing use of aluminum is greater use of welding as a means of joining aluminum structural members. It is important that those aluminum welds be nondestructively inspected. X-radiography is often used to assure the quality of aluminum welds.

Graded reference radiographs of welds, indicating the relative severity of indications such as porosity, inclusions, etc. are often used as an aid in judging the quality level and acceptance of a weld. These reference radiographs are available for steel welds, for example,[1] ASTM E390-73/84, "Standard Reference Radiographs for Steel Fusion Welds". However, the availability of graded reference radiographs for aluminum welds is limited.

Often, selected radiographs from ASTM E390 or similar steel weld radiograph reference documents are used to judge aluminum welds. However, one must recognize that the different X-ray attenuation properties of steel and aluminum lead to different contrasts of radiographic films. The radiographic appearances of discontinuities in aluminum and steel welds are not the same. The use of different X-ray energies and radiographic techniques lead to images that differ in contrast and sharpness. These differences are apparent to an experienced radiographic interpreter. The differences in image properties make it difficult to compare radiographs of steel and aluminum. These problems have led to contractual problems for the Army and other government agencies. Comparing a radiograph of an aluminum weld to a comparable thickness steel weld reference radiograph puts the contracting agency in a weak position concerning contract disputes over the acceptability of aluminum welds. The differences in image contrast and sharpness can lead to improper grading of weld quality and subsequent contractual disputes as inspectors differ over the weld quality indicated on a radiograph.

This Small Business Innovative Research (SBIR) Phase I investigation was directed toward the establishment of a data bank for a set of graded reference radiographs for aluminum welds. This data bank was to be developed by surveying government and industry facilities and collecting copies or original radiographs of aluminum welds. Where possible, the original hardware from which the radiographs were taken was to be either collected or cataloged by the facilities for future use.

The aluminum alloys of major interest are the 5000 (Mg series), 6000 (Mg and Si series) and 7000 (Zn series) alloys. The thicknesses of interest are the same as the thinner ones specified in ASTM E390, 0.03, 0.080, 3/16, 3/8, and 3/4 inch (0.8, 2.0, 4.8, 9.5 and 19mm), as a minimum. The defect types of interest, to be graded in severity levels, include lack of fusion, inadequate penetration (preferred term for incomplete penetration), tungsten inclusions, slag inclusions, linear porosity, clustered porosity, coarse scattered porosity and fine scattered porosity.

Specific objectives for the program included the following:

1. Establish a data bank of aluminum weld radiographs by contacts with government and industrial organizations.

2. Organize the data bank in terms of alloy thickness, type of defect, relative severity level and radiographic technique.

3. If the data bank proves adequate, prepare a plan for the establishment of a consensus standard by interactions with voluntary consensus standard organizations.

4. If the data bank is lacking, prepare a plan for completing the data bank. This will likely involve plans for a means to prepare aluminum welds (various alloys, thicknesses and geometries) containing various types of defects. Once samples become available, arrangement for radiographic testing and grading of the weld radiographs would be required.

5. Interact with voluntary consensus standard organizations to determine their procedural and technical requirements so radiographs produced in a Phase II program could serve as an acceptable basis for a consensus society standard.

6. Prepare a final report indicating the status of the data bank and the plans for development of a consensus standard.

PHASE I RESULTS

Collection of the Radiographic Data Bank

The initial efforts to collect a data bank of aluminum reference radiographs involved a literature search followed by the preparation of a letter and the selection of a mailing list to request help. The selection of people to receive the letter was based on discussions with the COTR and on the extensive radiographic experience and contacts of Industrial Quality, Inc. personnel.

The initial letter and the mailing list (65) are reproduced in Appendix A. Telephone follow-up contacts were made with many of the key individuals on the mailing list. These contacts and letter replies led, in many cases, to suggestions for other people or organizations to contact. A list of these extra contacts (9) plus 1 address correction is given at the end of the Appendix A mailing list.

All of the extra contacts were helpful. One in particular, Mr. Paul Dickerson of ALCOA, proved to be the source of an extended data bank of aluminum weld radiographs. Dickerson made available for the project several thousand radiographs of aluminum welds.

Several professional societies were also contacted to enlist their support in locating organizations that might have radiographs useful for the data bank. The letter and the mailing list are given in Appendix B.

During this initial phase of the data bank collection we were made aware of a 1974 report by the Army Tank Automotive Command (TACOM) on reference radiographs for aluminum welds.[2] The report included photographic prints of weld reference radiographs. In an effort to help the Army locate the original radiographs (and weld samples) we made an extended effort to find the report principal, Mr. Walter Wulf, who had retired from government service in 1977. Through personal contacts in professional societies we were able to locate Walter Wulf (address in Appendix A). He was very cooperative and provided a copy of his original report and information that was forwarded to TACOM to help them locate many of the original radiographs. Our information is that some of the original radiographs, primarily in the thickness range 19 to 38mm (0.75 to 1.5 inch), have been located.

Sorting the Data Bank into Graded Sets

During the program, a visit was made to the ALCOA Laboratories to review the weld radiographs offered by Paul Dickerson. Over 7000 weld radiographs were made available. Several sets of graded reference radiographs were selected from this large collection. The selections included several graded sets and several additional radiographs for illustrative purposes. The selected reference radiographs are outlined in Table 1.

The data bank of radiographs was extensively reviewed to determine if additional reference radiographs could be selected; that did not prove to be possible. Since the material thickness of most of the samples was 12.7mm (.50 inch) it is proposed that this reference set be applicable in the thickness range of 9.5 to 19mm (.375 to .750 inch). The radiographs were made of production items and, at times, experimental procedures that go back over twenty years. There is no hardware presently available for these radiographs. The welding procedure was MIG with the composition mostly aluminum alloy 6061 with some including 5083.

Prints were made of the radiographic negatives to illustrate the overall composition of the reference radiographs (Figures 1-5). What is shown in these illustrations is the suggested layout per page and the individual viewing area for a given grade. The selection of five grades for most of the illustrations was made to follow the format of ASTM-E390, Reference Radiographs for Steel Welds.[1]

Figure 1 illustrates grades 1-5 for fine scattered porosity. Figure 2 shows five grades of coarse scattered porosity. Five grades of linear porosity are illustrated in Figure 3. These three illustrations are shown as they are now envisioned for use in a reference radiographic document. Such a document would contain radiographic transparencies rather than photographic prints as shown here. Figures 4 and 5 are shown to illustrate other conditions. These figures are not necessarily as they might be grouped in a reference radiographic document.

Figure 4 shows three grades of clustered porosity and two examples of inadequate penetration. In a reference radiographic document these two classes of weld defects might be placed in separate illustrations. Figure 5 shows examples of several weld discontinuities, cracks, tungsten inclusions and undercut. The method for producing these photographic prints from the original radiographs is described in Appendix C.

The selection of three grades of clustered porosity follows the format of the TACOM report.[2] In that format any radiographic evidence of clustered porosity greater than grade 3 was designated to be distributed porosity and was to be evaluated accordingly.

The illustrations of inadequate penetration show a narrow interrupted defect and a relatively wide continuous defect. The recommendation is to use the approach suggested in the TACOM report; a given percent length of inadequate penetration per length of weld can be used to determine the grade.

The ungraded examples are shown to illustrate discontinuity types that arise primarily from a variety of incorrect welding procedures.

The original sets of reference radiographs, along with the remaining radiographs collected as part of the data bank, are being turned over to the Army Belvoir Research Development and Engineering Center as a deliverable under this program.

Table 1 - Selected Graded Reference Radiographs, By Category

Category	Number of Radiographs	Comments
Fine scattered porosity	5	graded set
Coarse scattered porosity	5	graded set
Linear porosity	5	graded set
Clustered porosity	3	graded set
Inadequate penetration	2	continuous; interrupted
Tungsten inclusions	2	localized at weld start; distributed
Cracks	2	longitudinal; transverse; lack of fusion
Undercut	1	longitudinal groove

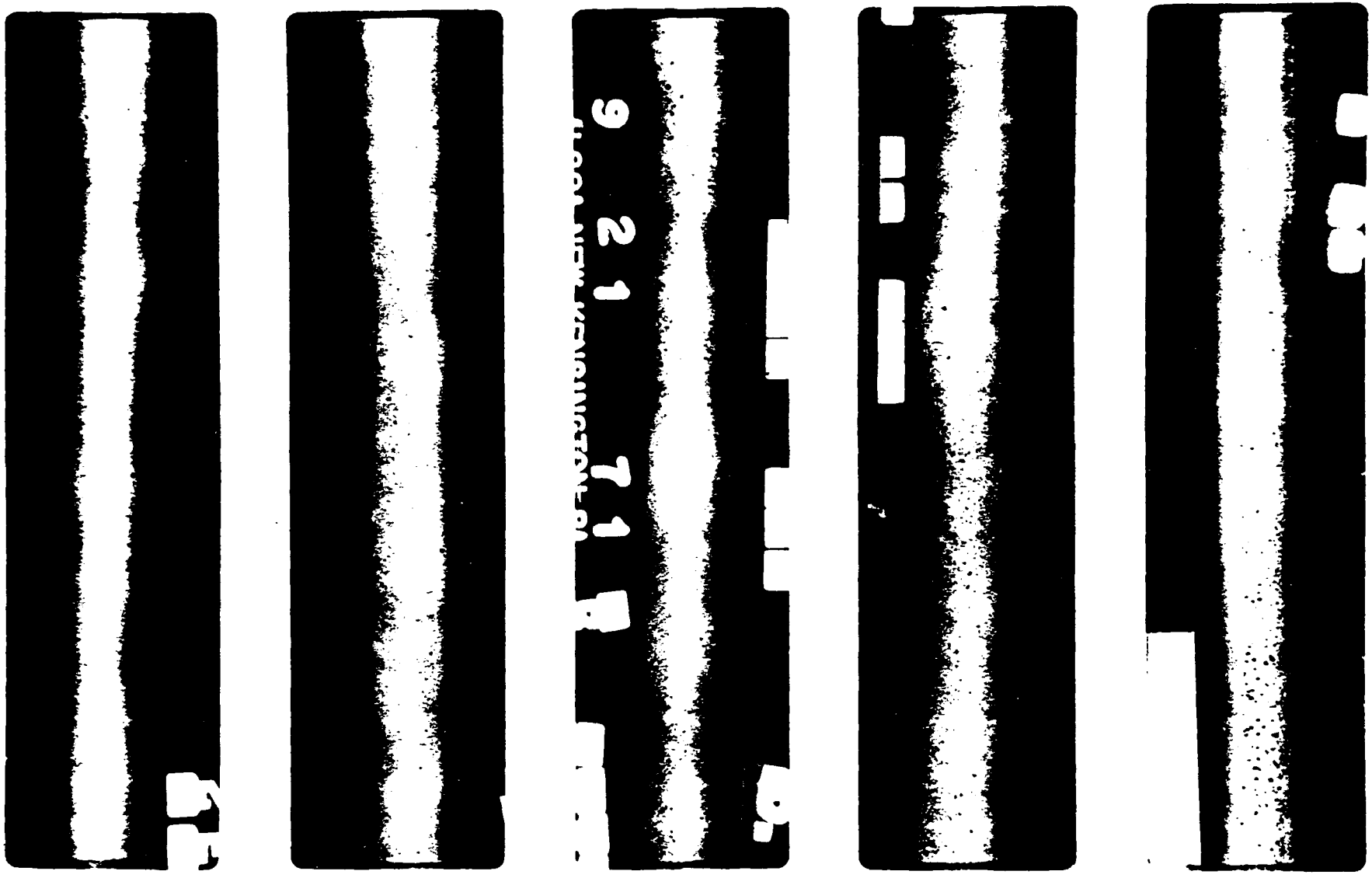


Figure 1. Fine Scattered Porosity

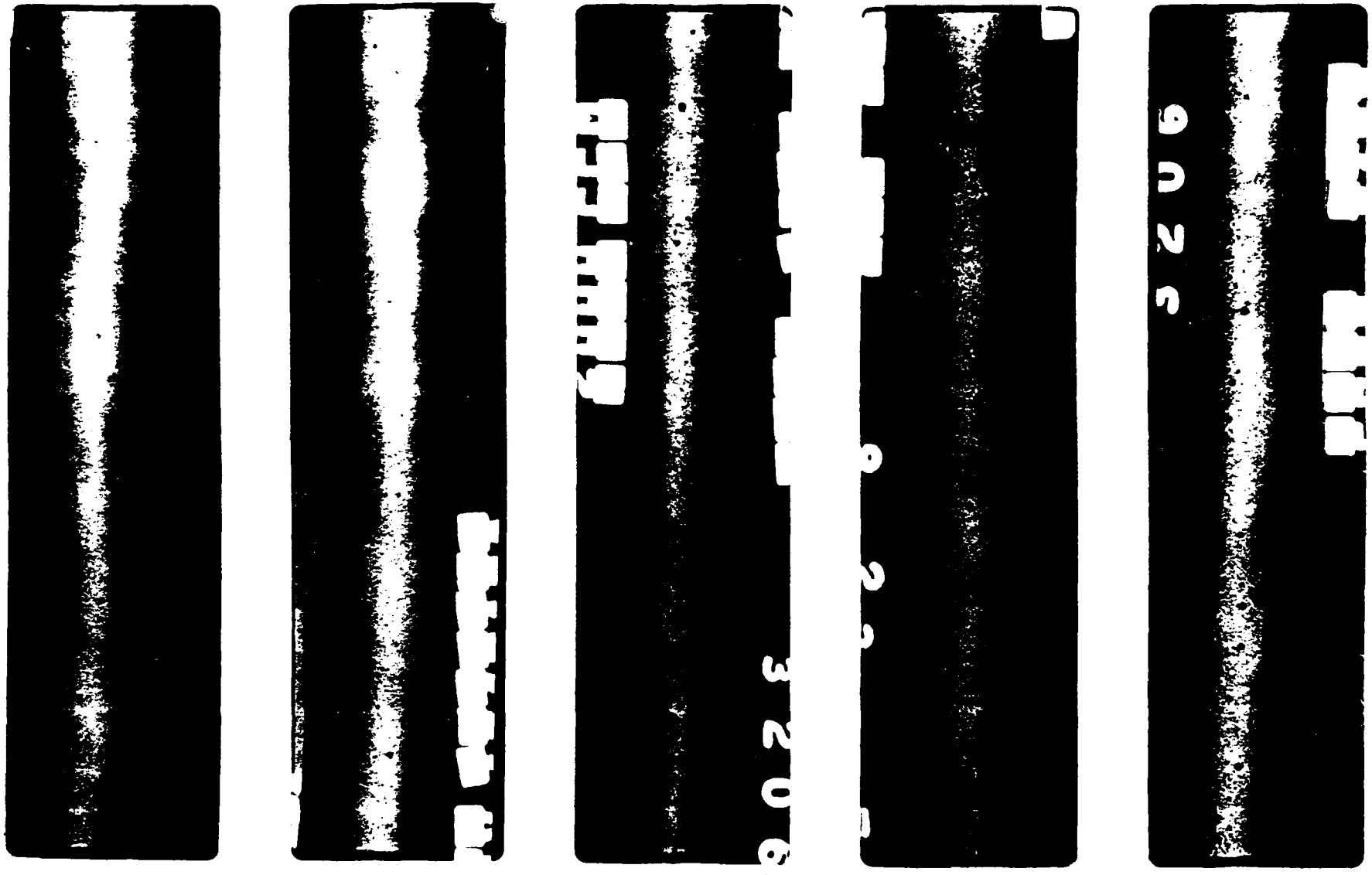


Figure 2. Coarse Scattered Porosity

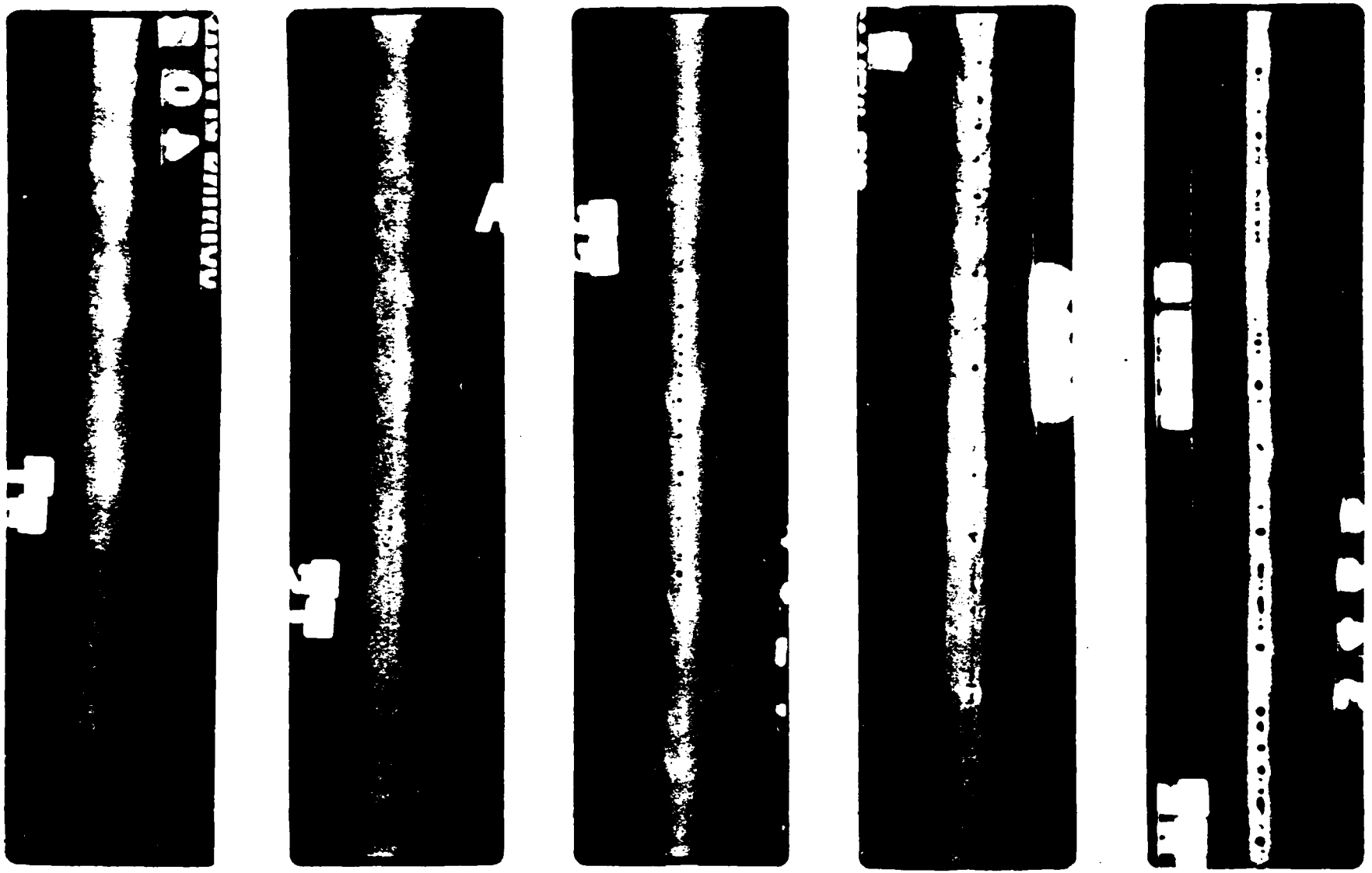
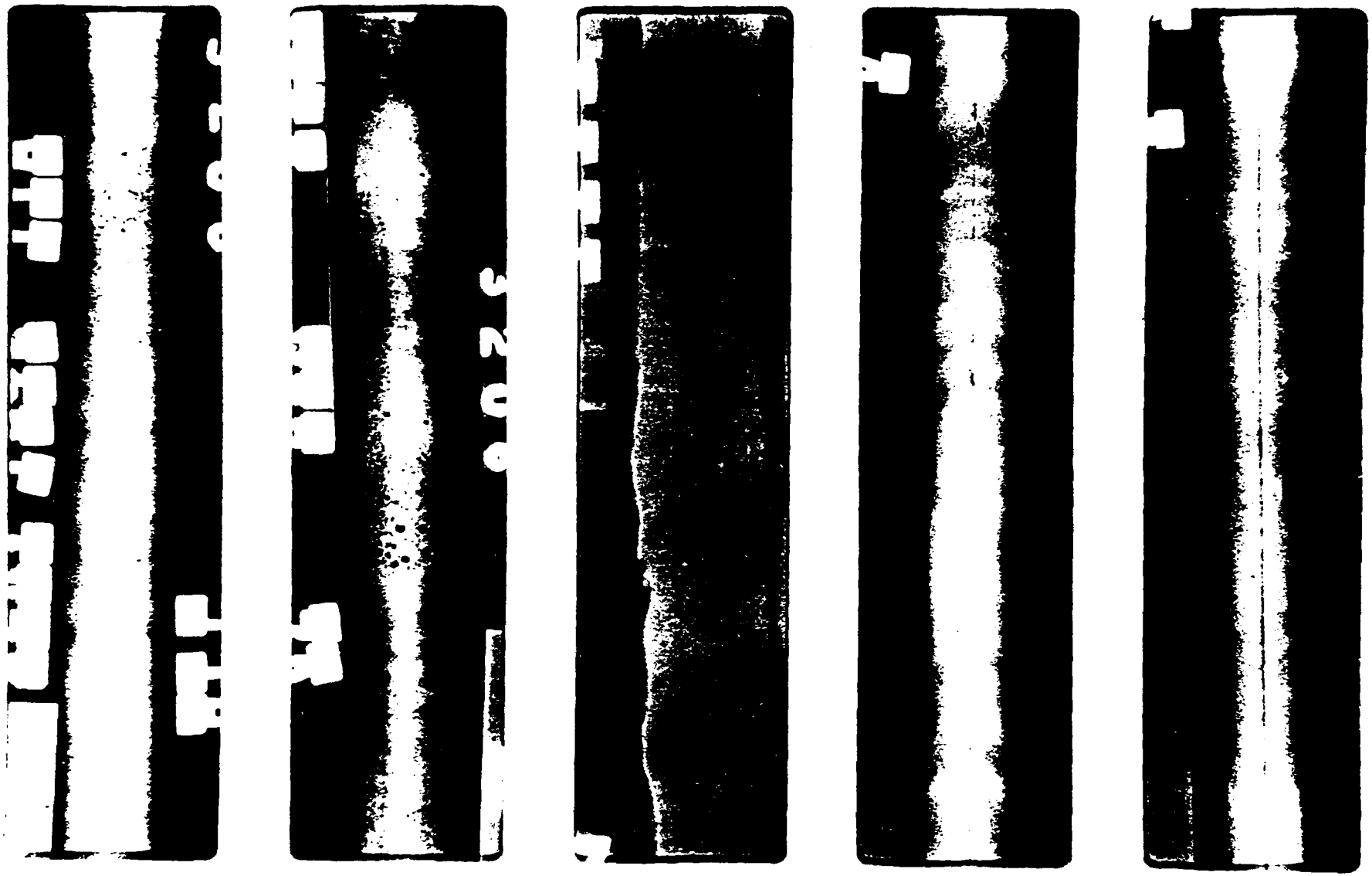


Figure 3. Linear Porosity



1 2 3

Figure 4.

Clustered Porosity

Inadequate Penetration

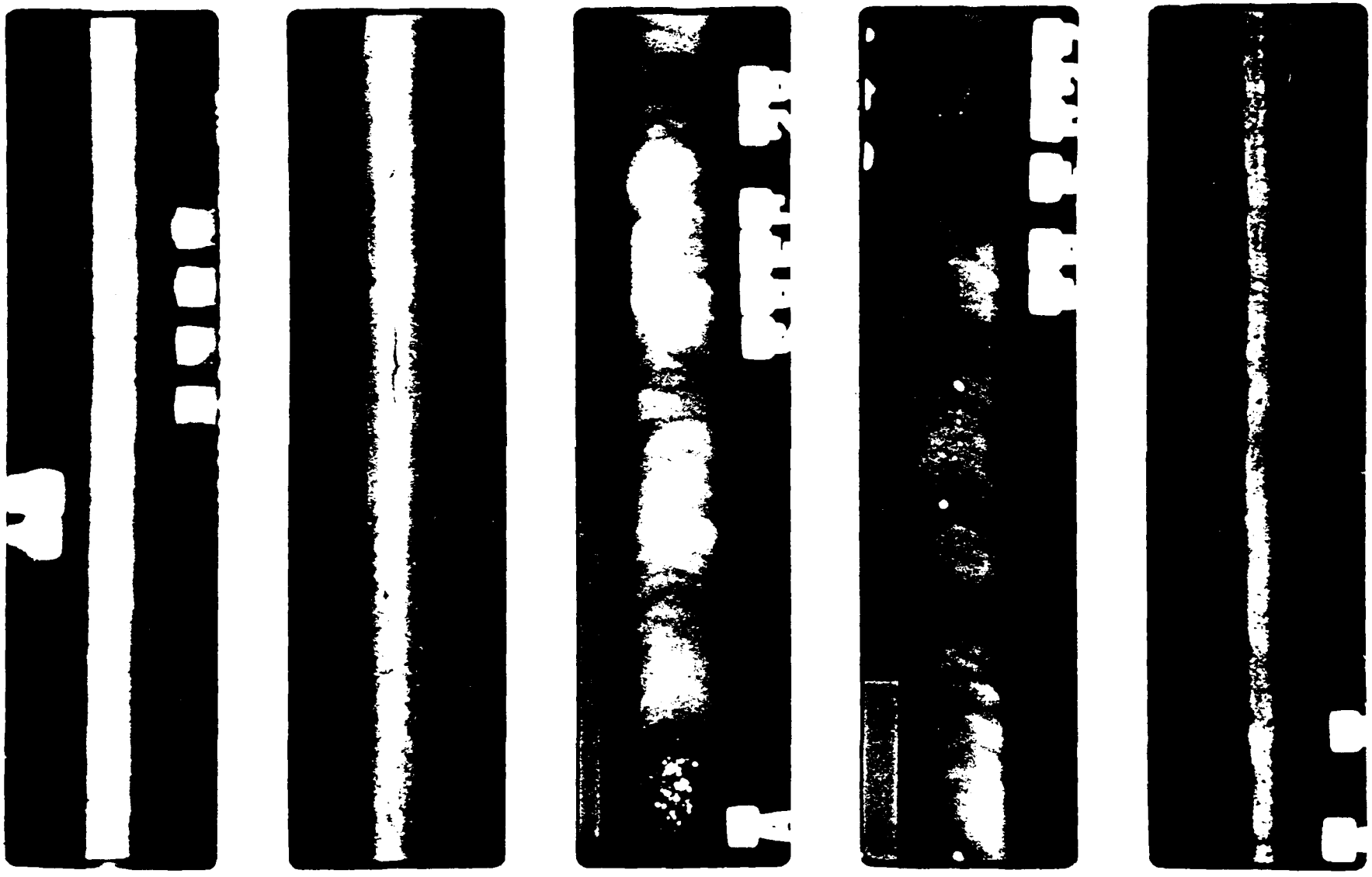


Figure 5.

Cracks

Tungsten Inclusions

Undercut

DISCUSSION

The radiographs shown in the photographic prints in Figures 1-5 represent a useful initial set of graded reference radiographs for aluminum welds. The set is limited in terms of thickness range and alloy type. As indicated in the previous section, the radiographs involve weld thicknesses primarily in the range of 9.5 to 19mm (0.375 to 0.75 inch). The alloys represented are primarily those in the 5000 and 6000 series.

Additional reference radiographs that are desirable include those for additional alloy series and those for extended thickness ranges. As in the case of the graded reference radiographs for steel,[1] it is desirable to use separate sets of reference radiographs for very thin and very thick welds. The radiographic contrasts are different in each case, thereby making it necessary to develop sets to cover only a limited thickness range. The set described in this report represents a thickness range from about 9.5 to 19mm (0.375 to 0.75 inch). A set to cover thin materials, up to 9.5mm (0.375 inch) is needed. Additional sets should cover the range from 19 to 75mm (0.75 to 3 inches) and from 75 to 200mm (3 to 8 inches).

The alloy compositions[3,4] of the 5000 (Mg series) and 6000 (Mg and Si series) are generally similar in terms of X-radiographic attenuation properties. The 7000 (Zn series) alloys tend to include more high atomic number additives (typically about 11%); this leads to higher X-ray attenuation for these alloys. Therefore, two sets of reference radiographs would be needed to cover the 5000, 6000 and 7000 series of aluminum alloys. The recommended sets of reference radiographs are outlined in Table 2. The present data bank covers only the set marked X.

A few radiographic transparency copies were prepared during this program to show the excellent quality radiographic copies that can be obtained. These were prepared by Parker Industrial Laboratory Corp[5], East Hartford, Connecticut, the same company that prepares the radiographic copies for the ASTM reference radiographic documents. ASTM, an organization that publishes several series of reference radiographic documents, uses radiographic transparency copies extensively. The cost of preparing original radiographs is high. The quality of the copies is excellent. The copies are reviewed by a technical group before acceptance. The copies are of such good quality that the rejection rate (as determined by experienced radiographers) is less than 5%.

The copies prepared by Parker are being made available to the Belvoir R, D&E Center as part of this contract. The copies clearly indicate a direction that would provide a useful reference radiographic document.

Industrial Quality, Inc. is aware of the strong interest in DOD to have the reference radiographs available and published as a standard maintained by a professional society. The American Society for Testing and Materials (ASTM) Committee E-7 on Nondestructive Testing includes Subcommittee E7.02 on Reference Radiographs. That Subcommittee has been responsible for the production of reference radiographs for over forty years. In their procedure, a document is presented for review and acceptance by the Subcommittee members (government and industry representatives). After successfully completing a ballot at this level, the document must be successfully balloted to the main committee (E-7) and then to the full society (ASTM). A decision is then made as to the production of multiple sets. In almost all previous documents, ASTM has required weld hardware to be available to produce more original radiographs. However, as indicated previously, radiographic transparency copies are now used predominantly in the reference radiographic documents in place of duplicate, original radiographs.

As part of the work under this contract several appropriate societies were contacted to judge their interest in accepting, publishing and maintaining sets of graded reference radiographs for aluminum welds. The societies contacted included the American Society for Nondestructive Testing (ASNT), ASTM and the American Welding Society (AWS). The letter sent to each society and the address used are given in Appendix B.

Table 2 - Recommended Sets of Graded Reference Radiographs For Aluminum Welds

Alloy Series	Thickness Ranges			
	Up to 9.5 mm (.375 in.)	9.5 - 19 mm (.375 to .75 in.)	19 - 75 mm (.75 to 3 in.)	75 - 200 mm (3 to 8 in.)
5000 6000		X		
7000				

X Only set of graded reference radiographs presently available

Our interactions with the societies included a meeting with the Chairman of ASTM E7.02, Mr. Walter Roy, a meeting with the AWS B-1 Committee on Methods of Inspection (and additional discussions with AWS Liaison member Hudson Walls), telephone discussions with George Luciw, Staff Manager at ASTM and Ronald Selner, Technical Director of ASNT, and correspondence with H. Glenn Ziegenfuss, Technical Director of AWS. Our impressions of these interactions are that all of these societies strongly support the need for graded reference radiographs of aluminum welds. Our discussions with ASTM and AWS are encouraging for the development of a consensus standard.

We have also discussed this project with representatives of national welding organizations, including Dr. Karl F. Graff, Executive Director, Edison Welding Institute and Dr. H.H.J. Vanderveldt, President, American Welding Institute. Both these welding leaders expressed support for the reference radiographic project. Perhaps more important, they also made it clear that their organizations could be of assistance in putting us in contact with appropriate people in industry and government who may be able to assist with more extensive search for data bank aluminum weld reference radiographs.

It is recognized that the data bank collected in this Phase I program is a valuable asset. This data bank will be maintained at the Belvoir R, D & E Center. It is hoped that societies and industrial organizations will continue to add to the data bank. A letter requesting such assistance is given in Appendix D, with the mailing list.

RECOMMENDATIONS

Industrial Quality, Inc is pleased that the data bank obtained during the Phase I program can provide the basis for a useful document. We recommend that additional work be done to make available a document that covers the present data bank, to expand the data bank to cover other aluminum alloys and thickness ranges, and to work with the professional societies to provide a consensus standard that will be published and maintained.

A specific near-term recommendation is to prepare multiple sets (25 to 100) of graded reference radiographs, as available now in the data bank, using radiographic transparency copies. A few of these sets can be used by the Army in its procurement. Other sets can be used to work with professional societies in an effort to obtain a consensus document.

In addition, work should begin to expand the data bank to fill in the gaps in Table 2, as needed. Our discussions with the COTR and the colleagues indicate less interest in the 7000 series alloys, since many of these materials are not recommended for welding. Therefore, it is our recommendations that emphasis be placed now on needs for the 5000 and 6000 series alloys.

On the matter of the different thickness ranges, there is a clear need to proceed to thinner materials. Military procurements related to vehicles and construction, for example, often involve the thinner aluminum materials. Extension of the data bank to cover the thickness from 0 to 9.5mm (0.375 inch) is recommended. If this were done, the present data bank, the radiographs located at TACOM and the new data bank would provide radiographs to cover the thickness ranges 0 to 9.5mm (0.375 inch, new data), 9.5 to 19mm (0.375 to 0.75 inch, present data bank) and 19 to 38mm (0.75 to 1.5 inch, TACOM radiographs).

The method to obtain these needed radiographs will likely involve a mixture of further data bank collection, and preparation and radiography of selected missing parts of the needed graded sets. Now that the Phase I program has caught the interest of many organizations involved in aluminum welded manufacture and construction, it is anticipated that arrangements could be made to obtain selected production radiographs illustrating graded weld conditions.

Work with the professional societies, particularly ASTM and AWS, should continue in this recommended follow-on program. The ideas provided by those knowledgeable groups of radiographic specialists will certainly contribute to a more useful set of graded reference radiographs. Strong interest has been expressed by individuals active in both ASTM and AWS.

In summary, the recommendations to implement graded reference radiographs of aluminum welds are as follows:

1. Prepare an interim reference radiographic document utilizing this Phase I set of radiographic transparency copies.

2. Use the interim document for Army procurements and for discussions with ASTM Subcommittee E7.02 and AWS Committee B-1 for consideration as a consensus standard.

3. Expand the data base, particularly to thinner weldments. This expansion should include work with aluminum weld production facilities and national welding organizations to gain their cooperation in getting original production radiographs. The expansion will likely also involve the preparation of deliberately faulted aluminum welds to fill in any gaps that may exist in the data bank.

4. Continue to work with ASTM Subcommittee E7.02 and AWS Committee B-1 to expand the availability of graded reference radiographs of aluminum welds.

Industrial Quality, Inc. plans to submit an SBIR Phase II proposal to pursue these objectives.

REFERENCES

1. Anon., "Standard Reference Radiographs for Steel Fusion Welds", ASTM E390-75/84, American Society for Testing and Materials, Philadelphia (1975, 1984).

2. M.V. Pyhtila and W.F. Wulf, "Reference Radiographs for Full Penetration Aluminum Weldments", TR 11891, U.S. Army Tank Automotive Command, Warren, MI (June, 1974).

3. W.F. Kehler, Editor, "Handbook of International Alloy Composition and Designation", Vol. III, Aluminum

4. H.E. Boyer and T.L. Gall, Editors, "Metals Handbook", Vol. 11, Am. Society for Metals, Metals Park, Ohio (1984).

5. L. F. Dandaneau, Private Communication, The Parker Industrial X-Ray Laboratory Corp., 272 Governer Street, East Hartford, Connecticut, 06108, Phone: (203) 289-7767, 17 November 1987.

Appendix A

Letter Sent to Industrial and
Government Organizations Concerning
Availability of Reference Radiographs of Aluminum Welds

and

Mailing List

Dear

Industrial Quality, Inc. has received a contract from the Belvoir Research, Development and Engineering Center at Fort Belvoir, Virginia to put together a set of graded reference radiographs of aluminum welds. The document visualized would be similar to ASTM E390, Standard Reference Radiographs for Steel Fusion Welds. We are presently trying to determine if there are well documented radiographic results on aluminum welds in existence that might be used to prepare such a reference document. Our purpose in writing to you is to request your assistance in this matter.

Do you or someone in your organization have radiographs of aluminum welds that might be used in a reference radiographic collection? Could these be made available to us in the form of original radiographs (preferred) or radiographic copies? Are you aware of other persons/organizations that we should contact?

As one who is acquainted with weld radiography, we are sure you recognize the value of a set of graded reference radiographs. To our knowledge, none exists for aluminum welds; this forces users to reference documents such as ASTM E390 for steel welds. The use of steel weld radiographs to judge the quality of aluminum weld radiographs obviously has some technical shortcomings. Therefore, we are pleased to be assisting the Army in the preparation of a document for graded reference radiographs of aluminum welds. The emphasis is on radiographs of aluminum (5000, 6000, and 7000 series alloys) butt welds (full penetration) made by the MIG welding process. Preferred thicknesses are *.03, .08, .1875, .375 and .75* inches. However, at this time we would welcome information/data about any aluminum weld radiographs.

Thank you very much for your help. We look forward to hearing from you.

Sincerely yours,

Daniel Polansky
Senior Physical Scientist

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Appendix B

Letter Prepared for Societies to Determine Interest
in Developing, Publishing, and Maintaining a
Reference Radiographic Standard for Aluminum Welds

and

Mailing List

Dear

The Belvoir Research, Development and Engineering Center at Ft. Belvoir, Virginia is leading a DoD effort to develop a standard containing graded reference radiographs of aluminum welds. Industrial Quality, Inc. is under contract to the Belvoir R, D&E Center to assist in this matter. The purposes of this letter are to (1) inform your Society about this project in the hope that appropriate technical committees may have information or material that would assist the effort and (2) request an indication of your Society's interest in assisting, particularly in the matter of developing, publishing and maintaining a recognized standard for graded reference radiographs of aluminum welds. As you are aware, DoD strongly encourages the use of recognized standards in all its activities.

The emphasis in the present program is on graded radiographs of aluminum (5000, 6000 and 7000 series alloys) butt welds (full penetration) made by the MIG welding process. Preferred material thicknesses are 0.03, 0.08, and 0.1875, 0.375 and 0.75 inches. However, we anticipate that there will be interest in other documents of graded reference radiographs of aluminum welds.

We hope to hear from you concerning the interest of your Society in assisting in this project and in developing a recognized Society standard. We should make you aware that we are approaching several other societies to determine their interest in supporting and publishing this standard.

Sincerely yours,

Daniel Polansky

DP/db

Proposed Mailing List

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cc: Walter Roy

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Mr. Ronald Selner
Technical Director
American Society for Nondestructive Testing
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Columbus, OH 43228-0518

Appendix C. Photographic Procedure for Producing Reference Radiograph Figures

The illustrations of the reference radiographs shown in this report were produced in a multi-step photographic process. This process was intended to produce illustrations of sufficient quality to communicate the types of indications and the relative severity of the indications. The illustrations are not intended to be used for the grading and acceptance of radiographs. The basic steps of this process were:

1. Place each reference radiograph on a viewer box and photograph the radiographic image using the light transmitted through the radiograph.

2. Print each of the radiographs to actual size.

3. Assemble the first generation prints into sets and dry mount on posterboard. Add 5 window matting and figure titles.

4. Rephotograph the assembled set.

5. Print the figure pages on 8-1/2 x 11 paper.

Details of each of these steps are included below.

1. The original radiographs were placed on a S & S X-ray Products, Inc. Model 460 X-ray film illuminator. This unit uses fluorescent tube illumination on a milk glass screen and produces a very uniform light of moderate intensity. The radiographs were masked with a cardboard window cut from the 5 window matting to show reveal only the intended section of the radiograph. The surrounding areas of the viewer were masked to prevent stray light from causing glare or reflections. The room lights were also turned off to avoid glare and reflection problems. The radiographs were photographed using a 35mm camera and Kodak T-MAX 100 Black and White film. The camera was used with a 135mm lens modified with a +1 diopter close-up lens. The long axis of the radiograph was allowed to nearly fill the frame of the 35mm negative. The light transmitted through the weld portion of each film was read and used to adjust the exposure for each radiograph. Exposures were typically on the order of 1/4 second at f8. Exposures were bracketed plus and minus one stop to ensure appropriate exposure. The film was tank processed in Kodak D-76 developer at a 1:1 dilution for 12 minutes at 68 deg. F.

2. The negatives were then printed to actual size on Kodak PolyPrint RC glossy finish paper with filtration set for approximately contrast grade 2-1/2. Exposures were adjusted to produce approximately uniform density in the weld zone. The prints were processed in Kodak Dektol at a 1:2 dilution for 90 seconds.

3. The prints were assembled into illustration sets and dry mounted with Kodak Spray Photo Mounting Adhesive on cardboard. A five window mask was added on top of the photographs to show only the originally selected zone of the radiograph. A title overlay was added to identify the weld radiograph illustrations.

4. The assembled illustration was rephotographed on a copy table with a Graflex Speed Graphic 4 x 5 camera and Kodak T-MAX 100 film. The films were exposed at f 16 for 1/8 second. The 4 x 5 films were tank processed in Kodak TMAX developer at full strength for 7 minutes at 72 deg. F.

5. The 4 x 5 negatives were commercially printed on Kodak glossy finish 8-1/2 x 11 paper to produce the illustrations in the report.

Appendix D

Letter Requesting Assistance in Adding
to the Data Bank at Belvoir R, D & E Center

and

Mailing List

February 12, 1988

Dear

You are aware of our program to assist the U.S. Army Belvoir R,D&E Center to prepare a data bank of material for a graded set of reference radiographs of aluminum welds. Our initial program is now drawing to a close. Some reference material has been obtained and an initial set of graded reference radiographs of aluminum welds covering the thickness range 3/8 to 3/4 inch has been proposed. The purpose of this letter is to emphasize the continued interest at the Belvoir R,D&E Center to assemble and store a data bank of material for this purpose. Please make it known to your organization and your colleagues that a data bank for graded sets of reference radiographs of aluminum welds remains an active interest for the U.S. Army. Submission of materials (welds and/or radiographs) for the data bank is encouraged at this central storage and evaluation location. Belvoir is willing to serve as a repository for these data until a Society consensus document is available. Materials for the data bank should be sent as follows:

U.S. Army Belvoir R,D&E Center
Attn: STRBE-VL, George D. Farmer
Fort Belvoir, VA 22060-5606

Tel. 703-664-5374

Thank you for your cooperation.

Sincerely yours,

Harold Berger, P.E.
President

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END

DATE

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